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REPORT NO. FAA-ASP-77-6

AN ANALYSIS OF CONTINUED OPERATION OF SELECTED AIRPORT TRAFFIC CONTROL TOWERS (ATCT)

JUNE 1977

DRAFT REPORT

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
OFFICE OF AVIATION SYSTEM PLANS
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16. Abstract

This report evaluates the merits of continued operation of existing FAA airport traffic control towers using the benefit-cost technique. Considered are airport safety and efficiency benefits as well as the costs of continued facility operation and of dismantling and relocation.

The analysis identifies 73 current tower locations as not worthy of continued operation on economic grounds. Only nine sites are selected as candidates for decommissioning when using existing noneconomic discontinuance criteria.

The study is divided into three parts. Part A describes the detailed benefit-cost rationale and methodology. Part B provides an historical account of the evolution of tower establishment and discontinuance criteria. Part C examines the impact of uneconomical tower locations identified by the benefit-cost analysis, i.e., those sites where costs of continued tower operation exceed benefits. This part also offers several alternative options for formulating an agency policy for discontinuing tower operations.

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EXECUTIVE SUMMARY

This report evaluates the merits of continued Federal operation of existing Airport Traffic Control Towers (ATCT) based upon benefit-cost (B-C) analysis.

The analysis evaluates the dollar-derived benefits of enhanced safety and operation efficiency at tower airports and compares the cumulative benefit to the cost of continued operation over a 15-year forecast period. Towers with benefits not exceeding costs are identified as locations for possible discontinuance when based upon pure economic grounds.

The benefit-cost methodology is applied to 425 tower airports listed in the FAA Terminal Area Forecast. Using operations data for FY 1978, 73 commissioned towers are identified with costs exceeding benefits. This has major significance when compared to the impact of current ATCT discontinuance criteria which identify only 9 sites in FY 1978.

Current criteria, pertaining to facilities presently commissioned or programmed, are not based upon benefit-cost considerations. Instead, criteria are defined purely on the basis of annual itinerant operation counts. Compounding the significance of existing criteria versus benefit-cost analysis is the fact that tower discontinuance criteria contain grandfather clauses. These clauses relate specific activity levels for ATCT discontinuance to criteria in effect at the time of tower programming.

Several options for further evaluating towers identified through benefit-cost analysis are presented in the latter part of the report (Part C). These alternatives do not involve additional analytic computation; instead, they represent suggested decision rules on a rational application of the B-C methodology to tower discontinuance determinations. Acceptance of some or all of these alternatives, when compared to 73 sites identified by full application of the benefit-cost procedure, could reduce the impact by over 50 percent.

INTRODUCTION

This report evaluates the merits of continued operation of existing FAA airport traffic control towers using benefit-cost analysis. Considered are the safety and delay reduction benefits of tower establishment as well as the cost of continued operation and the cost of tower relocation should decommissioning occur.

The report is divided into Parts A, B, and C. Part A describes the detailed benefit-cost rationale and methodology as applied to existing tower facilities. All currently commissioned towers are evaluated and a sensitivity analysis performed.

Part B provides a brief historical account of tower establishment and discontinuance criteria. From the account, the reader can trace the trend of establishment criteria becoming tighter while candidates for discontinuance remain unaffected through the use of grandfather clauses in successive criteria revisions.

Part C examines the impact of uneconomical tower locations identified by the benefit-cost analysis, i.e., those sites where costs of continued operation exceed benefits. This part also offers several alternative options for formulating a policy for discontinuing towers, based upon either existing criteria or the benefit-cost technique, should this study be accepted as a rationale for a basis for revising tower discontinuance criteria.

PART A

I - BENEFIT-COST TECHNIQUE

General Description

Benefit-cost (B-C) analysis is the technique whereby costs are compared with the dollar value of derived benefits in order to ascertain a measurement of investment worth. Benefit-cost is not, nor should it be, the sole procedure in arriving at decisions to establish, improve, replace, or discontinue facilities. However, the B-C technique is the prime tool from which facility and equipment (F&E) establishment criteria are currently derived.

Facility and equipment criteria development (as related to the FAA mission) pertains to safety (reducing the probability of an accident or severity of an accident) and efficiency (benefit of saving time). Analysis of facility benefits remains fairly constant whether we are performing a benefit-cost analysis for establishment or for discontinuance. Cost considerations, however, differ considerably.

While the assigned dollar value of benefits is weighed against capital, operating, and maintenance costs for establishment candidates, capital costs are considered sunk when evaluating candidates for discontinuance.

The treatment of discontinuance candidates is not complete until we have evaluated additional costs and benefits not addressed above. Ancillary benefits (not included under safety or efficiency); facility salvage value; dismantling, shipping, and storage costs; and the cost of providing replacement service (whenever necessary) all must be factored into the benefit-cost equation.

This section will examine ATCT costs. The benefits of tower facilities will then be reviewed. Much of the detailed background information is contained in:

> Report No. ASP-75-4, "Establishment Criteria for Airport Traffic Control Towers (ATCT)," DOT, FAA, Office of Aviation System Plans, October 1975.

ATCT Costs

Current representative annual costs for towers operating 16 hours a day (except where noted) are listed in Table 1. Cost data cannot be consistent for all towers. When considering a 15-year forecast period as is done here, costs based on generalized staffing requirements are considered sufficient for indicating expected tower expenditures over the forecast.

Staffing costs are based upon:

1 Chief, GS-12 step 4, + 20 percent for overhead,

6 Controllers, GS-10 step 4, + 20 percent (one less controller for towers operating 8 hours or less per day),

½ Secretary, GS-5 step 4, + 20 percent, and

1 Maintenance Person, GS-11 step 4, + 20 percent

Relocation costs are estimated at $3,000 for each employee, excluding secretary.

Staffing costs are provided by AAT-120; ATCT leased space and GSA vehicle costs are provided by ALG-12; utility and dismantling costs are supplied by AAF-510.

Tower Benefits

It is the primary responsibility of the tower controller to maintain the separation of aircraft in the air, in the airport control zone, and on the airfield and to expedite the flow of traffic. He accomplishes this by directing pilots on the radio and issuing (or denying) clearance. The controller determines the aircraft's position he receives from the pilot by radio or by visual reference to the aircraft.

On the average, the aircraft are controlled by radio within five miles of the airport and are seen by the controller within three miles. In matters of air traffic control, the controller has full authority. However, he has no authoritative control over other pilot actions, such as flying into adverse weather. He is nevertheless able, in some cases, to advise pilots of hazardous conditions, such as obstructions on the airport site, a glide slope angle which could result in an undershoot, or landing gear not extended.

TABLE 1

Annual ATCT Discontinuance Costs

O&M	Cost
Chief	$ 25,589
Controller Staffing	117,403
(8 hours/day tower operation)	(97,836)
Secretary	6,070
Maintenance Staffing	21,457
Leased Lines	7,200
Stocks and Stores	1,700
Utilities	6,000
GSA Vehicles	1,200
ATCT Leased Space	1
Total O&M	$186,620
Dismantling/Relocation	
Controllers	$ 21,000
Maintenance	3,000
Dismantling	100,000
Total	$124,000
Salvage Value	$ 5,000
Replacement Service	
Universal Communication Equipment (Unicom)	$ 15,000

Also, the tower controller is in a position to summon aid for a pilot when needed, e.g., firefighting equipment, search and rescue. Thus, the total safety effectiveness of towers is a result of more than the primary function of separating traffic.

Tower benefits can be broken into three main categories:

- Benefits from prevented midair collisions
- Benefits from prevented accidents
- Benefits from reduced flying time

In addition to those listed above, there is a fourth benefit category which can be termed subjective:

- Direct and indirect economic benefits to the community and benefits due to the facility being part of a larger overall system

A. Benefits from Prevented Midair Collisions

A statistical comparison was made for the years 1961-68 of midair collisions at tower and nontower airports having 20,000 to 60,000 itinerant aircraft operations annually and 40,000 to 150,000 total aircraft operations annually. The National Bureau of Standards, after making an analysis of the measured differences in midair collisions, concluded that the lower rate of such midair collisions at the tower airports was statistically significant evidence of the safety effectiveness of VFR towers. The analysis found that 22 midair collisions in the 8-year period occurred at nontower airports with annual itinerant operations in the 20,000 to 60,000 range. Only one of the collisions occurred at an FAA tower airport in the same operation range. Measured as a rate, there were 0.6 midair collisions per million operations at airports without FAA towers and 0.03 at FAA tower airports.

B. Benefits from Prevented Accidents

An analysis parallel to that for midair collisions was made for other types of aircraft accidents. This analysis was slightly more complicated, however, in that the accidents which were "tower-preventable" had to be selected through a rather lengthy processing of a mass of accident data from the National Transportation Safety Board (NTSB).

The first step in this procedure was to obtain a selected list of general aviation and air carrier accidents for the years 1964 through 1968 from the NTSB data system. All those which by their causal description and other factors seemed to be of a kind preventable by VFR tower control were printed out in the brief form. This eliminated over half of the annual total number of accidents.

The resulting list of briefs was then screened to select accidents which were considered to be "tower-preventable." Nine types of such accidents were identified:

1. Wheels-up landings, with malfunction in the wheels-up warning systems. These were cases in which the wheels-up warning horn or the position indicator light(s) did not function properly, and there was no indication that the gear retraction and extension mechanism itself was inoperative. Theoretically then, an accident would be prevented if the pilot is warned by the controller of their retracted position. No wheels-up landings occurring during the nighttime were included in this or the following category.

2. Wheels-up landings, with no malfunctions in warning systems. In this category, the wheels-up landings appeared to be the result of an error by the crew which could perhaps have been corrected by a controller warning.

3. Collisions between aircraft, one in the air and one on the ground. This is clearly one of the kinds of accidents VFR tower control should prevent. It was noted in reading the description of these accidents that there was occasionally some difficulty in determining whether the accident should be classified as two aircraft colliding in the air or as one in the air and one on the ground. This was especially true when one of the aircraft was just lifting off the runway.

4. Collisions between two aircraft, both on the ground. In this category, both aircraft are moving along a taxiway or runway. Eliminated were collisions in areas which the tower controller could not be watching, e.g., hangar areas.

5. Collisions of aircraft with other objects. "Other objects" include construction barriers or other unusual hazardous objects of which the controller could warn the pilot. When the accident seemed to be due to pilot error which a controller could not or would not anticipate (e.g., colliding with parked aircraft), the accident was not selected for the analysis.

6. Landing on wrong runway relative to existing wind. This category includes cases where the aircraft landed in the wrong direction relative to the wind.

7. Not aligned with the runway (or intended landing area). The tower controller could theoretically spot an aircraft's being in danger of landing off the runway and warn the pilot of the erroneous heading.

8. Overshoots. If one of the other categories described above seemed to apply to an accident in which the pilot overshot the runway, the accident was placed in that category. For instance, when landing on the wrong runway relative to the existing wind, the pilot may also overshoot the runway. The accident would then have been placed in the previous category.

9. Undershoots. These accidents were tabulated by type of accident, by their occurrence at tower and nontower airports, and by the number of itinerant and total operations at the airports. This was done for both numbers of accidents and rates of accidents per million operations in each of the five years for a five-year total and for totals at the airports that fall in the operations range.

C. Benefits from Reduced Flying Time

There are also several ways in which VFR tower control can make possible more efficient approach and landing of an aircraft for a saving of aircraft operating costs and time. An example of this kind of effectiveness is the VFR tower controller's being able to clear an aircraft for a straight-in approach, because he has the knowledge that there is no conflicting traffic. At a nontower airport, the usual procedure for a pilot would be to first circle the airport to check for traffic and wind direction. This is not to maintain that reduction of congestion delay is a benefit attributable to VFR control towers at airports with low amounts of annual traffic. With such volumes of traffic at airports, there is only a small likelihood of delays building up. However, there are savings in flying time, and it is conceivable that at higher volumes of traffic VFR tower control would be effective in reducing aircraft delays.

D. Other Benefits

These benefits are not computed as they are considered nonquantifiable but are nevertheless acknowledged to exist

in some capacity. Included here are benefits of providing advance information to other facilities and aircraft, providing emergency in-flight assistance, participating in search and rescue activities, acting as communication center in times of natural disasters, and stimulating the local economy.

It is appropriate here to note the fact that nonquantified benefits are not unique to analysis of towers. In evaluating the functions of any facility, there exist additional factors beyond the realm of analytical techniques. Subjective weighting of benefits to handle these "intangibles" only serves to cloud the high degree of accuracy obtainable with "known" parameters.

II - IDENTIFICATION OF BENEFIT-COST EXPRESSION

The generalized benefit-cost (benefit-minus-cost) method involves the evaluation of the following expression:

$$\sum d_i(B_i-C_i) + d_{16}(S-D) + \sum d_iU_i + (D-S)$$

where:

d_i = discount factor for year i

B_i = benefits in year i

C_i = O&M costs in year i

S = salvage value

D = dismantling costs

U_i = cost of providing replacement service (e.g., Unicom)

The B-C formula is a mathematical description of the dollar benefits of continued tower operations over a forecast period of 15 years. Subtracted from these benefits are the costs of continued Federal operation for the same time frame. As we are forecasting over 15 years, both costs and benefits are expressed in terms of present worth. Current dollar values of benefits and costs are used; future values will be multiplied by appropriate discount factors. If discounted costs exceed discounted benefits, the net benefit-cost expression is negative.

For the reader requiring a more detailed explanation of the benefit-cost formula, the following is an explicit description of terms.

The benefit-cost formula for ATCT evaluation may be written as follows:

$$\sum d_i(B_i-C_i) + d_{16}(S-D) < - \sum d_iU_i - (D-S)$$

In this form, we are comparing the net benefits (benefits minus costs) of continued tower operation (left-hand portion of the expression) with the costs of decommissioning at the present time (right-hand portion). If net benefits of continued operation are less than immediate decommissioning costs, the tower may be worthy for discontinuance. Benefits are denoted with positive coefficients; costs have negative coefficients.

$(B_i - C_i)$ is the annual dollar value of benefits, B (as described in Section I), minus annual operating and maintenance costs, C, for year i. $(B_i - C_i)$ is then multiplied by a discount factor, d_i, for year i. A discount rate of 10 percent is applied in accordance with specifications in OMB Circular A-94, Revised; $d_i(B_i - C_i)$ is computed for each year of a 15-year period and then summed. No major capital improvements are anticipated during the 15-year period and therefore none are considered in the benefit-cost formula. $\sum_{i=1}^{15} d_i(B_i - C_i)$ thus represents the net benefits (benefits minus costs) of continued tower operation for 15 years at a 10 percent discount rate. Table 2 lists appropriate discount factors for use in ATCT B-C computations.

S-D, when multiplied by the appropriate discount factor, is the benefit of deferred dismantling. This term is the difference between the salvage value obtained from surplus equipment and the actual cost of tower dismantling and storage of components (including shipping to the depot). As an ATCT is assumed to continue operations for 15 years (see above paragraph), (S-D) is multiplied by d_{16}, the discount factor in the 16th year, at which time the tower is presumed to be decommissioned.

$-U_i$ is the cost of providing replacement service for a tower in year i should the tower be decommissioned at the present time. Specific to ATCT criteria, a Unicom is provided in many nontower fields. A Unicom is a nongovernment air/ground communications facility which may provide airport advisory service at airports. U_i's are discounted over 15 years and summed as the cost of providing continuous replacement service for towers immediately discontinued.

-(D-S) represents the current cost of ATCT dismantling. Analogous to the d_{16}(S-D) term, which represents the benefit of deferred dismantling at the end of the 16th year, (D-S) is the present cost associated with expenditures for removal

TABLE 2

10% Discount Factors

End of Year	Discount Factor Single Amount (d_i)	Cumulative (Σd_i)
1	0.9091	0.909
2	0.8264	1.736
3	0.7513	2.487
4	0.6830	3.170
5	0.6209	3.791
6	0.5645	4.355
7	0.5132	4.868
8	0.4665	5.335
9	0.4241	5.759
10	0.3855	6.144
11	0.3505	6.495
12	0.3186	6.814
13	0.2897	7.103
14	0.2633	7.367
15	0.2394	7.606
16	0.2176	7.824

minus revenue gains from equipment salvage value. (D-S) is not discounted as it represents current costs (where the discount factor is 1.00).

Comparing the net benefits of 15-year operational benefits of deferred decommissioning, or:

$$\sum_{i=1}^{15} d_i(B_i-C_i) + d_{16}(S-D)$$

with the cost of decommissioning now, or:

$$-\sum_{i=1}^{15} d_i U_i - (D-S)$$

if net benefits are less than costs, an ATCT is operating at an economic loss. Therefore,

$$\sum_{i=1}^{15} d_i(B_i-C_i) + d_{16}(S-D) < -\sum_{i=1}^{15} d_i U_i - (D-S)$$

or:

$$\sum_{i=1}^{15} d_i(B_i-C_i) + d_{16}(S-D) + \sum_{i=1}^{15} d_i U_i + (D-S) \quad 0$$

III - METHODOLOGY FOR DETERMINING THE BENEFIT-COST VALUE OF AIRPORT TRAFFIC CONTROL TOWERS

The generalized methodology for determining the annual benefits of control towers is a summation of the several benefit elements which relate prevented collision rates, accident rates, and time-loss rates to the costs of these occurrences if no control tower were established. Additional economic benefit elements are considered but are not as yet specifically quantified. As benefits are discounted over 15 years, the following computations will be computed 15 times, once for each year. The detailed methodology is as follows:

where:

Total benefits (B_i) = ($B_1 + B_2 + B_3$) x discount factor for year i

$$\text{Net benefits} = \sum_{i=1}^{15} d_i(B_i - C_i) + d_{16}(S-D)$$

B_1 = Benefits from prevented midair collisions

B_2 = Benefits from prevented accidents. (Accidents shown to occur less frequently at tower airports. Included are collisions on the ground or with objects, overshoots, misaligned with runway, landing on wrong runway with respect to wind, and wheels-up landings.)

B_3 = Benefits from reduced flying time (the time saved by not having to overfly an airport to determine landing direction, airport, and traffic conditions)

C_i = Annual tower operating and maintenance costs in year i

d_i = Discount factor for year i

The remainder of this section describes in detail how each of the three benefit elements is computed. Reference is made to the source of the cost and probability factors which are used for the benefit computation.

1. **Benefits from Prevented Midair Collisions (B_1)**

The benefits from prevented collisions (B_1) are estimated as follows:

$$B_1 = P \sum_{i=1}^{m} X_i C_i$$

Where:

P = "Preventable" collision rate (annual)

$$P = S\left(.0292642\right)\left(\frac{O_T}{80}\right)^{1.3}$$

And:

O_T = Annual total operations (000), e.g., 50,000 annual total operations = 50.0

P is based on the historical difference between midair collision rates at tower and nontower airports in the 40,000 to 150,000 annual total operation range over an 8-year period. It is an adjusted "best fit" function describing the relationship between "tower preventable" collision rates and traffic volume. The function includes factor S, which is used to account for the statistical uncertainty in the mean values. The National Bureau of Standards determined that midair collision rates at tower and nontower airports were statistically significantly different. On the basis of this determination, the difference in rates between tower and nontower airports is assumed to be "tower preventable" collisions. The basic collision rate data and additional categorizations of the data are contained in Report No. ASP-75-4, "Establishment Criteria for Airport Traffic Control Towers," Office of Aviation System Plans, October 1975.

X_i = Ratio of operations of aircraft class i to total operations. Classes currently included are:

- Class 1 = certificated route air carrier operations

- Class 2 = air taxi operations

- Class 3 = military operations under 12,500 lbs. (light)

- Class 4 = military operations between 12,500 lbs. and 25,000 lbs. (medium)

- Class 5 = military operations 25,000 lbs. and over (heavy)

- Class 6 = general aviation itinerant operations

- Class 7 = general aviation local operations

C_i = Cost of collisions between the two aircraft in class i

Also:

$$C_i = 2\left[R_i(k_i L_i + l_i I_i) + D_i A_i\right]$$

Where:

R_i = Average number of persons aboard an aircraft of class i

k_i = *Fraction of those persons aboard an aircraft of class i* receiving fatal injuries in a collision

l_i = Fraction of those persons aboard an aircraft of class i receiving severe injuries in a collision

L_i = Liability for a fatal injury received aboard an aircraft of class i

I_i = Liability for a serious injury received aboard an aircraft of class i

D_i = Average damage factor for aircraft of class i involved in collision--includes approximately 10 percent for accident investigation costs, baggage loss, etc.

A_i = Average value of aircraft of class i

Current values used for the above items are shown in Table 3.

TABLE 3

Current Values of Collision Cost Elements ($000)

	P_i	k_i	($000) L_i	l_i	($000) I_i	D_i	($000) A_i
1 - Air carrier	40.0 1/	0.5 4/	300.0 6/	0.005 4/	61.8 6/	.75 5/	4500.0 8/
2 - Air taxi	6.6 2/	↓	↓	0.1	↓	↓	200.0 2/
3 - Military (light)	2.5	0.36	↓	↓	↓	↓	30.0 9/
4 - Military (medium)	6.6	0.5	↓	↓	↓	↓	200.0
5 - Military (heavy)	10.0	↓	↓	0.005	↓	↓	4500.0
6 - General aviation itinerant	2.5 3/	0.36 5/	↓	0.1 5/	↓	7/	30.0
7 - General aviation local	2.0 3/	↓	300.0	↓	61.8	↓	20.0

1/ "Estimated Number of Persons to be Served by ILS's and ATCT's in FY 1970 Program," National Bureau of Standards for the FAA, June 1970.

2/ "Commuter Airlines," Report Number 3, July 1975. Estimated average seat availability as 10 per aircraft. Average load factors estimated at 46 percent plus a crew of 2 for a total of 6.6 persons aboard.

3/ "Study of General Aviation Flying Occupant Load Factors," FAA, Office of Management Systems, May 1970.

4/ "Annual Review of U.S. Air Carrier Accidents, 1967-1968," NTSB.

5/ "Analysis of the Costs and Effectiveness of Air Traffic Control Towers," Second Interim Report, FAA, Office of Aviation Economics, September 1970.

6/ From CAB non-Warsaw Pact accident payments for period 1966 to 1970 - extrapolated to 1974 (modified for consistency with other analyses).

7/ "Annual Review of Aircraft Accident Data U.S. General Aviation 1967, 1968, 1969."

8/ Estimated on the basis of the average values of DC-9, B-727, and B-737 aircraft.

9/ "An Analysis of ARTS III Terminal Area Automation System - Benefits and Costs," Office of Aviation Policy and Plans, FAA, November 1969.

2. Benefits from Prevented Accidents (B_2)

The benefits from prevented accidents (B_2) of the types shown to have less frequency of occurrence at tower airports are estimated as follows:

$$B_2 = \sum_{i=1}^{m} P_i X_i C_i$$

Where:

P_i = Annual "preventable" accident rate for aircraft class i

For all classes except air carrier and military (heavy) operations:

$$P_i = S\left[\frac{1}{1.66267 + O_T(-0.00318934)}\right]$$

For air carrier (ac) and military - heavy (mh) operations:

$$P_i \text{ (ac or mh)} = S\left[\frac{O_T(0.00665)}{25}\right]$$

And:

O_T = Annual total operations

S = Factor to account for statistical uncertainty in mean value--factor S is set at 2

P_i was determined on the basis of the difference in accident rates at tower and nontower airports over a 5-year period. It is a best-fit function describing the relationship between average accident rates and traffic activity. Since the accident rates for air carriers were significantly lower than for other types of operations, these rates are shown separately.

Basic accident rates and additional categorizations are contained in Report ASP-75-4, "Establishment Criteria for Airport Traffic Control Towers," Office of Aviation System Plans, October 1975.

X_i = Ratio of operations of aircraft of class i to total operations

C_i = Average costs of accidents for aircraft of class i

And:

$C_i = R_i(h_i L_i + I_i g_i) + d_i A_i$

Where:

h_i = Fraction of those aboard an aircraft of class i receiving fatal injuries in an accident

g_i = Fraction of those aboard an aircraft of class i receiving serious injuries in an accident

d_i = Average damage factor for aircraft of class i involved in accidents

The remainder of the symbols are the same as those shown under C_i for the B_1 computation.

Current values used for the above items are shown in Table 4.

3. Benefits from Reduced Flying Time (B_3)

Benefits from time saved (B_3) at control tower airports are estimated as follows:

$$B_3 = \sum_{i=1}^{m} F_i q_i x_i f_i$$

TABLE 4

Current Values of Accident Cost Elements ($000)

Class (i)	R_i	h_i	L_i	g_i	I_i	d_i	A_i
1 - Air carrier	40.0	0.0 1/	300.0	0.0 1/	61.8	.3	4500.0
2 - Air taxi	6.6	0.005		0.01		.5	200.0
3 - Military (light)	2.5					.5	30.0
4 - Military (medium)	6.6					.5	200.0
5 - Military (heavy)	10.0	0.0		0.0		.3	4500.0
6 - General aviation itinerant	2.5	0.005 2/		0.01 2/		.5 3/	30.0
7 - General aviation local	2.0	0.005	300.0	0.01	61.8	.5	20.0

1/ "Annual Review of U.S. Air Carrier Accidents 1967-1968," NTSB.

2/ "An Analysis of the Costs and Effectiveness of Air Traffic Control Towers," Second Interim Report, FAA, Office of Aviation Economics, September 1970.

3/ "Annual Review of Aircraft Accident Data - U.S. General Aviation 1967, 1968, 1969."

Where:

F_i = Average extra flying time (minutes) for an aircraft of class i to overfly an airport to determine landing direction, airport conditions, traffic conditions, etc.

x_i = Annual operations of aircraft class i

q_i = Fraction of operations of aircraft class i which overfly airport

f_i = Direct and indirect operating cost (per minute) for an aircraft of class i

Currently used values are estimated as shown in Table 5.

4. <u>Summation of Benefits</u>

Sum benefit values B_1, B_2, and B_3 in steps 1 through 3 above. For operations data for each year i in the Terminal Area Forecast data base, call $B_1 + B_2 + B_3$ by B_i.

5. <u>Determination of $\sum_{i=1}^{15} d_i(B_i-C_i) + d_{16}(S-D)$</u>

Steps 1 through 4, above, are repeated for each B_i for each of the 15 years with data from the Terminal Area Forecast. In its published format, the Forecast covers a 10-year period. For this study, the Office of Aviation Policy has created a forecast data base for each fiscal year, 1975 through 2001. This study uses FY-78 operations data as a base year since if revised benefit-cost methodology were adopted, FY 78 would probably be the first year of implementation. Successive B_i's are then computed through FY 92.

Next, subtract current annual O&M costs (C) given in Table 1 from each B_i. Although costs vary according to tower and length of forecast, variances (largely due to staffing fluctuations) are dampened over the 15-year forecast period. Two levels of staffing costs are used in the analysis--one for towers operating over 8 hours/day (\$117,403), and the other for those operating 8 hours/day or less (\$97,836). (See Table 1.) O&M costs are considered equal

TABLE 5

Current Values of Time Saved Elements

	F_i	q_i	f_i \$/min.
Class 1 - Air carrier	---	0	9.00
Class 2 - Air taxi	1.5	.10	2.80
Class 3 - Military (light)	1.5	.25	.42
Class 4 - Military (medium)	1.5	.25	2.80
Class 5 - Military (heavy)	1.5	.25	9.00
Class 6 - General aviation itinerant	1.5	.25	.42
Class 7 - General aviation local	1.5	.125	.42

throughout the total forecast period before discounting back to present worth.

Using the discount factors appearing in Table 2, multiply each $B_i - C_i$ by the appropriate d_i. Sum from i=1 to 15 years to find the dollar value of net tower benefits over 15 years. Added to this sum is the value of $d_{16}(S-D)$ where current values of S and D are given in Table 1.

6. <u>Determination of ATCT Discontinuance Costs</u>

Costs to decommission an existing FAA airport traffic control tower are given by:

$$-\left[\sum_{i=1}^{15} d_i U_i + (D-S)\right]$$

Where:

U_i = Annual cost of providing replacement service in year i

D = ATCT dismantling costs

S = Salvage value

d_i = Discount factor for year i

Nondiscounted costs of providing tower replacement service are considered constant over time. Substituting appropriate values for all the variables given in Steps 5 and 6, the total B-C expression is evaluated.

$$\sum_{i=1}^{15} d_i(B_i-C_i) + d_{16}(S-D) + \sum_{i=1}^{15} d_i U_i + (D-S)$$

If the value of the expression is negative (once all the substitutions are made), the tower is considered a poor investment based upon economic merit.

IV - AN ILLUSTRATION ON COMPUTING THE BENEFIT-COST VALUE

Steps 1 through 11 below describe in detail how the benefit-cost value for an individual location is computed. In lieu of the mathematical formulas used to compute the cost and probability factors, tables have been made available to determine these factors for specific levels of operation. The following steps describe the process for a single year only. Benefit calculations must be repeated for each year of the 15-year forecast period.

Reference Figure 1, Format for Computation of Benefit-Cost Value.

Step 1

In column 1, enter the forecast annual operations by class (certificated route air carrier; air taxi; military heavy, military medium, or military light; general aviation itinerant; and general aviation local). For convenience in computing, list the annual operations in thousands, e.g., 20,000 annual operations = 20.0. Sum the values for the classes to determine the annual total operations (designated by the symbol T).

Step 2

In column 2 of Figure 1, determine the portion of the total traffic that is certificated route air carrier, air taxi, military, etc., by dividing the values in column 1 by the total annual operations (T).

Enter the quotients in column 2. The sum of the quotients should equal 1.

Step 3

Insert collision costs in column 3 of Figure 1. Military (light), general aviation (itinerant), and general aviation (local) have a fixed cost factor as the number of occupants remains fairly constant across each aircraft category.

Reference Table 6 to determine collision costs for air carrier and military (heavy). Reference Table 7 to determine collision costs for air taxi and military (medium). If forecast data concerning the average number of persons aboard is available, use the costs associated with the appropriate

Figure 1. Format for Computation of Benefit-Cost Value for Year 1
Lewisburg, West Virginia (FY 78 = year 1)

TYPE OPERATION	COLUMN 1 ANNUAL OPERATIONS (000)	COLUMN 2 ANNUAL OPERATIONS BY CLASS ÷ TOTAL ANNUAL OPERATIONS	COLUMN 3 COLLISION COSTS	COLUMN 4 WEIGHTED COLLISION COSTS	COLUMN 5 ANNUAL BENEFITS FROM PREVENTED COLLISIONS
Air carrier					
Air carrier	2.0	0.105	18,774.72	1,971.35	
Air taxi	1.0	0.053	2,361.58	125.13	P = .009
Military - light	0.0	0.0	615.90	0.00	B_1 = P x G
Military - medium	0.0	0.0	2,636.58	0.00	B_1 = 23.23
Military - heavy	0.0	0.7	12,762.36	0.00	
General aviation - itinerant	11.0	0.579	615.90	356.61	
General aviation - local	5.0	0.263	486.72	128.01	
	T = 19.0 Total Annual Operations			G = 2,581.10 Average Collision Cost for Mix	P = Preventable Annual Collision Rate

TYPE OPERATION	COLUMN 6 ACCIDENTS COSTS	COLUMN 7 PREVENTABLE ANNUAL ACCIDENT RATE BY CLASS (Q)	COLUMN 8 ANNUAL BENEFITS FROM PREVENTED ACCIDENTS	COLUMN 9 ADJUSTED COSTS OF DELAY BY CLASS	COLUMN 10 ANNUAL BENEFITS FROM REDUCED FLIGHT TIME
Air carrier	1350.00	.010	1.42	0.0	0.00
Air taxi	113.98	1.248	7.54	.42	0.42
Military - light	20.30	1.248	0.00	.16	0.00
Military - medium	113.98	1.248	0.00	1.05	0.00
Military - heavy	1350.00	.010	0.00	3.38	0.00
General aviation - itinerant	20.36	1.248	14.71	.16	1.76
General aviation - local	14.24	1.248	4.67	.08	0.04
			B_2 = 28.34		B_3 = 2.58

NOTE: All costs and benefits except for values of column 9 are expressed in thousands of dollars ($000).

$B_i = B_1 + B_2 + B_3 = 54.15$ $\qquad C_i = 167.05$

$d_i(B_i - C_i) = d_i(-112.90)$

$$\sum_{i=1}^{15} d_i(B_i - C_i) + d_{16}(S-D) + \sum_{i=1}^{15} d_i U_i + (D-S)$$

$$\sum_{i=1}^{15} d_i(B_i - C_i) - .2176\ (119.00) + 114.09 + (119.00)$$

$$\sum_{i=1}^{15} d_i(B_i - C_i) + 207.20$$

TABLE 6

Air Carrier and Military (Heavy)
Collision Costs ($000)

Persons Aboard	Collision Costs
10	9756.18
20 1/	12762.36
30	15768.54
40 2/	18774.72
50	21780.90
60	24787.08
80	30799.44
100	36811.80

1/ Used as average number of persons aboard military (heavy) flight in absence of specific data.

2/ Used as average number of persons aboard air carrier flight in absence of specific data.

TABLE 7

Air Taxi and Military (Medium)
Collision Costs ($000)

Persons Aboard	Collision Costs
6.6 1/	2361.58
10	3423.60
15	4985.40
20	6547.20
30	9670.80
40	12794.40

1/ Used as average number of persons aboard air taxi and military (medium) flight in absence of specific data.

Note that these cost values are in thousands of dollars.

average number of persons aboard. If this data is not available, use those typical averages cited in the footnotes to Tables 6 and 7.

Step 4

In column 4 of Figure 1, determine the weighted costs by multiplying the values from column 2 by the corresponding values from column 3. Enter the products in column 4, then add the products to determine the average collision costs for the mix of traffic which is designated by the symbol G.

Step 5

In column 5 of Figure 1, enter the preventable annual collision rate which is designated by the symbol P. This rate is obtained from Table 8 based on the total of annual operations which was computed in Step 1 and placed in column 1.

TABLE 8

Preventable Annual Collision Rates (P)

Annual Total Operations (000)	P All Categories
10.0	.004
20.0	.010
30.0	.016
40.0	.024
50.0	.032
60.0	.040
70.0	.049
80.0	.059
90.0	.068
100.0	.078
110.0	.089
120.0	.099
130.0	.110

Multiply the preventable annual collision rate (P) by the average collision cost (G), column 4, to determine the dollar benefits from prevented collisions. These benefits are designated as B_1 and the amount is entered in column 5.

Step 6

The accident costs are inserted in column 6 of Figure 1. Note that the air carrier, military (light), military (heavy), general aviation (itinerant), and general aviation (local) all have a fixed cost factor which is preprinted in column 6, Figure 1. Reference Table 9 to determine accident costs for air taxi and military (medium). If data concerning the average number of persons aboard is available, use the costs associated with the appropriate average number of persons aboard. If this data is not available, use the typical average cited in the footnote to Table 9.

TABLE 9

Air Taxi and Military (Medium)
Accident Costs ($000)

Persons Aboard	Accident Costs
6.6 *	113.98
10	121.18
15	131.77
20	142.36
30	163.36
40	184.72

* Used as average number of persons aboard air taxi and military (medium) flight in absence of specific data.

Step 7

In column 7 of Figure 1, enter the preventable annual accident rate. This rate is obtained from Table 10 based on the total of annual operations which was computed in Step 1 and placed in column 1. This rate is designated by the symbol Q. Note that there are two general groupings of operation type: one set of accident rates for the group air carrier and military (heavy) and another set for the group air taxi, military (light, medium), and general aviation (itinerant, local).

TABLE 10

Accident Rate (Q) by Class

Annual Total Operations (000)	Q	
	Air Carrier Military (Heavy)	Air Taxi, Military (Light, Medium), General Aviation (Local, Itinerant)
10.0	.005	1.226
20.0	.011	1.251
30.0	.016	1.276
40.0	.021	1.303
50.0	.027	1.330
60.0	.032	1.359
70.0	.037	1.389
80.0	.043	1.421
90.0	.048	1.454
100.0	.053	1.488
110.0	.059	1.525
120.0	.064	1.563
130.0	.069	1.602

Step 8

For each type of operation, multiply the values computed in column 2, Figure 1, by the corresponding average accident costs shown in column 6, by the corresponding preventable annual accident rate (Q) shown in column 7. Enter these values in column 8. These numbers represent the annual dollar benefits from prevented accidents by type of operation. Add the values in column 8 to determine the total annual dollar benefits from prevented accidents. These benefits are designated as B_2.

Step 9

In column 9, Figure 1, adjusted average costs of delay caused by overflying the airport to determine runway and traffic information are shown by type of operation. Multiply the number of annual operations in column 1 by the corresponding values in column 9. Enter these values in column 10. These numbers represent the annual dollar benefits from reduced flight time by type of operation. Add the values in column 10 to determine the total annual dollar benefits from reduced flight time. These benefits are designated as B_3.

Step 10

On the bottom of the Computation of Benefits Form, Figure 1, add the values of B_1, B_2, and B_3. This sum (B_i) represents the total benefits (not yet discounted) expressed in thousands of dollars for year i. Subtract the annual O&M C_i cost from B_i and multiply the appropriate discount factor for year i. Note the Lewisburg tower operates 8 hours/day so the associated C_i is \$167,053. (See Table 1.) Discount factors are listed in Table 2.

Step 11

Repeat Steps 1-10 for each year (i = 1 through 15), multiplying each (B_i-C_i) by the appropriate d_i. Sum over 15 years and add 207.20 (from bottom line of Figure 1) to the total. If the grand total is negative, the tower costs exceed benefits.

Computerization of Benefit-Cost Methodology

Fortunately, the previous calculations need not be tediously generated by hand. A computer program (written in Fortran IV) performs the requisite calculations. Using the expanded Terminal Area Forecast (through FY 2001) as input to the program, the Office of Aviation System Plans is able to ascertain which towers currently commissioned have negative benefit minus cost values. Should costs or benefit values change, or forecast data be revised, modification to the program can readily be accomplished.

V - IMPACT AND SENSITIVITY ANALYSIS OF BENEFIT-COST TECHNIQUE AS APPLIED TO ATCT'S

The benefit-cost technique, when applied to 425 towered airports listed in the FAA Terminal Area Forecast, identifies 74 sites with negative B-C values. These sites are listed in order of decreasing B-C in Table 11. (See column entitled "Actual Forecast.") Special considerations such as air carrier training activity, strategic military requirements, unusually rough terrain, or site remoteness were not addressed here. Instead, benefit-cost calculations were applied across-the-board using annual operations data for air carrier, air taxi, general aviation, and military aircraft as documented in the Forecast. O&M cost data was modified downward for those towers operating 8 hours/day or less.

The computation of the benefit-cost value involves many numerical factors which are used to quantify the value of benefits. Most of these factors have a constant value for a specific class of aircraft, i.e., the dollar value of a fatal or serious injury or the value of an aircraft.

There are, however, less definitive factors which, when varied, greatly affect outputs. Such is the case with fluctuations of aircraft activity data.

Data as listed in the Terminal Area Forecast was altered by aircraft class. Air carrier, air taxi, general aviation, and military aircraft operations were varied by a fixed percentage for each year in the 15-year forecast period FY 78-FY 92. The outcomes, in terms of towers identified with negative B-C values, are illustrated in Table 11 for a 5 percent and a 10 percent decrease in annual operations according to each aircraft class and a corresponding increase in operations data.

TABLE 11

Sensitivity of B-C Analysis to Forecast

Tower	10% Decrease	5% Decrease	Actual Forecast	5% Increase	10% Increase
Phoenix (Deer Valley), Ariz.	- 17				
Tuscaloosa, Ala.	- 20				
Riverside, Cal.	- 43				
South Lake Tahoe, Cal.	- 43				
Columbia, Mo.	- 48				
Helena, Mont.	- 50				
Groton, Conn.	- 50				
Salina, Kans.	- 58				
Lewiston, Ida.	- 60				
Lancaster, Cal.	- 63				
Tyler, Tex.	- 79	- 21			
Battle Creek, Mich.	- 94	- 37			
Palmdale, Cal.	- 98	- 34			
Waco, Tex.	-101	- 36			
Paducah, Ky.	-123	- 63	- 1		
Chico, Cal.	-125	- 64	- 2		
College Station, Tex.	-130	- 70	- 8		
Florence, S.C.	-146	- 84	- 21		
Bloomington, Ill.	-152	- 89	- 26		
Cleveland (Burke), Ohio	-146	- 89	- 30		
Traverse City, Mich.	-161	- 98	- 34		
Cape Girardeau, Mo.	-170	-109	- 47		
Goodyear, Ariz.	-194	-132	- 69	- 5	

TABLE 11 (cont'd)

Tower	10% Decrease	5% Decrease	Actual Forecast	5% Increase	10% Increase
Benton Harbor, Mich.	-196	-136	- 75	- 12	
Mayaguez, P.R.	-148	-129	-111	- 92	- 74
McAllen, Tex.	-234	-177	-119	- 60	- 1
Imperial, Cal.	-227	-175	-122	- 68	- 13
Texarkana, Ark.	-234	-180	-124	- 68	- 11
Muncie, Ind.	-238	-183	-127	- 71	- 13
Alexandria, La.	-253	-196	-138	- 79	- 19
Terre Haute, Ind.	-245	-193	-141	- 87	- 33
Enid, Okla.	-257	-200	-143	- 84	- 25
Key West, Fla.	-239	-193	-146	- 98	- 50
Meridian, Miss.	-267	-212	-156	- 99	- 41
Lawton, Okla.	-273	-217	-160	-102	- 44
Jacksonville (Craig), Fla.	-262	-217	-172	-125	- 78
Poughkeepsie, N.Y.	-255	-216	-177	-137	- 97
Ogden, Utah	-289	-234	-178	-122	- 64
Flagstaff, Ariz.	-286	-234	-181	-128	- 74
Salinas, Cal.	-294	-241	-187	-132	- 76
Hutchinson, Kans.	-300	-249	-198	-146	- 92
Redding, Cal.	-299	-252	-205	-156	-107
Appleton, Wisc.	-295	-252	-208	-164	-119
New Bern, N.C.	-298	-254	-209	-164	-118
Greenville, S.C.	-315	-264	-211	-158	-104
Pendleton, Ore.	-340	-292	-243	-193	-142
Marion, Ill.	-341	-294	-247	-199	-150
Merced, Cal.	-329	-289	-248	-206	-165
Jackson (Hawkins), Miss,	-361	-314	-266	-217	-167
Olympia, Wash.	-344	-307	-269	-231	-192
St. Petersburg (Whitted), Fla.	-364	-318	-271	-223	-175
Harlingen, Tex.	-368	-322	-276	-230	-182
Greenville, Miss.	-383	-336	-288	-240	-191

TABLE 11 (cont'd)

Tower	10% Decrease	5% Decrease	Actual Forecast	5% Increase	10% Increase
Kinston, N.C.	-371	-332	-293	-253	-213
Ithaca, N.Y.	-390	-345	-299	-253	-207
Brownsville, Tex.	-407	-362	-316	-270	-223
Twin Falls, Ida.	-388	-354	-321	-287	-252
Valdez, Alas.	-352	-340	-326	-313	-300
Bloomington, Ind.	-409	-370	-330	-290	-249
Hickory, N.C.	-415	-374	-333	-291	-249
Fresno (Chandler), Cal.	-430	-389	-347	-305	-262
Myrtle Beach, S.C.	-415	-382	-349	-316	-282
Ardmore, Okla.	-446	-403	-358	-314	-268
Santa Fe, N.M.	-460	-422	-384	-345	-306
Walla Walla, Wash.	-447	-423	-399	-374	-349
Tacoma (Industrial), Wash.	-482	-444	-405	-365	-325
Laredo, Tex.	-498	-458	-417	-376	-334
Hagerstown, Md.	-497	-472	-447	-421	-396
Valdosta, Ga.	-506	-479	-451	-424	-396
Athens, Ga.	-528	-491	-453	-415	-377
St. Joseph, Mo.	-531	-494	-456	-418	-379
Pine Bluff, Ark.	-528	-496	-462	-429	-395
Wheeling, W.Va.	-540	-506	-471	-436	-400
St. Louis (Spirit of), Mo.	-539	-507	-475	-442	-409
Danville, Ill.	-541	-516	-490	-464	-437
Knoxville (Downtown), Tenn.	-578	-546	-513	-479	-445
Spartanburg, S.C.	-580	-551	-521	-491	-460
Owensboro, Ky.	-579	-551	-522	-429	-463
Marysville, Cal.	-582	-554	-526	-497	-468
Lewisburg, W.Va.	-586	-568	-550	-531	-513
Brunswick, Ga.	-581	-567	-552	-537	-522
Plainview, Tex.	-706	-683	-659	-636	-611
Hobbs, N.M.	-736	-714	-692	-670	-647

TABLE 11 (cont'd)

Tower	10% Decrease	5% Decrease	Actual Forecast	5% Increase	10% Increase
Galesburg, Ill.	-743	-722	-701	-679	-658
West Memphis, Ark.	-786	-768	-749	-730	-710
Kodiak, Alas.	-808	-790	-771	-752	-732
Miami (Dade), Fla.	-919	-909	-898	-887	-876
Total Sites with B-C $<$ 0	87	77	73	65	63
Total Discounted B-C Value (000)	-29,470	-25,518	-22,070	-18,417	-16,015

PART B

VI - BRIEF HISTORY OF ATCT CRITERIA

Part B provides the reader with a background knowledge of tower criteria. Acquaintance with the criteria serves to illustrate the recent dramatic changes to establishment ground rules with retention of a conservative approach to discontinuance considerations.

Since 1951, ATCT establishment criteria have appeared in Airway Planning Standard Number One. Discontinuance criteria were not published until 1956.

Collectively, there have been three changes to ATCT criteria and two to discontinuance criteria (See Table 12). With each change, establishment criteria have identified fewer candidates than their predecessors. Current establishment criteria (approved October 1975) are forecast to identify 37 sites over the FY-74 through FY-86 period. This is a dramatic reduction in candidates when compared to the previous criteria (December 1969) which would have identified 144 towers for establishment over the identical time frame.

Traditionally, discontinuance criteria have retained grandfather clauses which relate the discontinuance of a tower to criteria in effect at the time of tower programming or establishment. As described in Table 12, the change of December 1969 retains former discontinuance criteria for towers established under previous revisions to establishment criteria. In this case, at airports without scheduled air carrier service, either 18,000 or 37,500 annual itinerant operations were defined as discontinuance levels depending on when the tower was programmed.

The most recent change of October 1975 retains both the 18,000 and 37,500 itinerant operations levels for discontinuance at general aviation airports depending on whether towers were programmed prior to or after 1968. All towers programmed during or after 1977 will have discontinuance criteria set at a sum of ratio value of 0.65 (See Part C, Section VIII for a detailed description of current discontinuance criteria).

TABLE 12

Brief History of ATCT Criteria

Dates	Establishment Criteria	Discontinuance Criteria
3/51 - 6/56	(a) 7,000 or more annual air carrier operations, or (b) weighted average of air carrier, itinerant and local operations for airports having between 4,000 and 7,000 annual air carrier operations, (c) special consideration for multiple airports at large metropolitan areas and for satisfying special safety requirements	No criteria
7/56 - 11/69	24,000 or more annual itinerant operations	18,000 annual itinerant operations
12/69 - 9/75	(a) Air commerce - An airport having scheduled air carrier service with 24,000 or more annual itinerant operations (b) General aviation - An airport without scheduled air carrier service with 50,000 or more annual itinerant operations	(a) Air commerce airport - less than 18,000 annual itinerant operations (b) General aviation airport - prior to 1968 less than 18,000 annual itinerant operatons (c) General aviation airport - during or after 1968, less than 37,500 annual itinerant operations
10/75 - present	AC/15,000 + AT/25,000 + GA&Mil/200,000 $\geq$ 1.0 plus benefit-cost study	(a) Air commerce airport - 18,000 annual itinerant operations (b) General aviation airport - programmed or established prior to 1968 - 18,000 annual itinerant operations (c) General aviation airport - programmed or established during or after 1968 - 37,500 annual operations (d) Towers programmed during or after 1977 - AC/15,000 + AT/25,000 + GA&Mil/200,000 <0.65 plus benefit-cost study

In summary, application of ATCT discontinuance criteria depends on the programming date of tower establishment at each candidate site. Historically, while establishment criteria are identifying fewer candidates with each revision, discontinuance criteria, through the use of grandfather clauses, "protect" towers otherwise identified for discontinuance by subsequent criteria revisions.

Perhaps the most effective description of ATCT discontinuance criteria application can be given by example:

Tower	Airport Type	Year of Programming	Current Annual Itinerant Operations
A	General Aviation	1960	30,000
B	General Aviation	1970	30,000
C	Air Commerce	1970	30,000
D	Air Commerce	1978	30,000

Tower	Current Discontinuance Criteria Satisfied
A	No
B	Yes
C	No
D	Depends on traffic mix and subsequent outcome of benefit/cost analysis

PART C

VII - PERSPECTIVE

At this point, we are ready to evaluate the various alternative courses of action in modifying or not modifying existing ATCT discontinuance criteria. Before proceeding, let us review the scope of this report.

Part A describes the benefit-cost approach in analyzing the worth of continued operation for all 425 towers currently commissioned. Safety and efficiency benefits of continued operation are quantified and compared to tower operating, maintenance, and relocation costs. Benefit-cost calculations are performed over a 15-year forecast period to account for air traffic growth at each airport. If benefits do not equal or exceed costs, the benefit-cost (B-C) expression yields a negative value. In total, 73 sites are forecast to have negative values in FY 78. In other words, at all 73 locations are derived benefits below costs of continued operation.

Part B presents a concise history of ATCT establishment and discontinuance criteria from 1951 to the present. The trend of establishment criteria has been to tighten qualifying levels for tower establishment. However, the existence of grandfather clauses in discontinuance criteria retains discontinuance levels based upon establishment requirements in effect at the time of tower programming. The effect of these clauses enables towers to continue operations at locations that otherwise would qualify for decommissioning had current criteria applied. The latest change of October 1975 bases future tower establishments on a benefit-cost justification for each candidate site identified by simple numeric criteria. Towers established or programmed during or after 1977 will qualify for discontinuance if justified by the benefit-cost technique. Towers established or programmed prior to 1977 will be "protected" by grandfather clauses.

Part C, the remainder of this report, investigates the effect of employing alternative options in formulating revised ATCT discontinuance criteria. These options are founded upon the benefit-cost methodology presented in Part A. The methodology, if formulated into criteria, is not intended to function as a black box, one where additional considerations would be ruled out. Instead, modification of the B-C determination may be required on the basis of special air traffic

control, military, economic, or political requirements. Each requirement would have an impact on a decommissioning program should revised criteria be applied.

Options examined in Part C for the development of ATCT discontinuance criteria are the following:

- Retain existing ATCT discontinuance criteria.

- Identify candidates for discontinuance on benefit-cost analysis of Part A.

- Identify candidates for discontinuance on benefit-cost analysis constrained by year of future tower reestablishment.

- Modify benefit-cost analysis by subjectively increasing benefits by 10, 20, or 30 percent. Increases in benefits could be attributed to quantifying lost intangible socioeconomic benefits (if any) associated with removal of existing commissioned towers.

- Other considerations.

These options, whether considered individually or collectively, should be included in the decision process on determining the approach to take in revising ATCT discontinuance criteria. Careful consideration should be given to each option with an evaluation of the associated impacts. The remainder of this report examines these alternative approaches and resultant impacts.

VIII - RETAIN EXISTING ATCT DISCONTINUANCE CRITERIA

Existing discontinuance criteria for airport traffic control towers, as defined in Airway Planning Standard Number One, identify 12 facilities using CY-1976 activity data. Identification and discussion of these sites are found below. Existing criteria are stated before addressing specific locations.

Discontinuance

A control tower established or programmed prior to 1977 is a candidate for decommissioning when activity falls below a predetermined level depending on the type of airport. These levels are:

(1) Air Commerce Airport - less than 18,000 annual itinerant operations.

(2) General Aviation Airport

(a) Established or programmed prior to 1968 - less than 18,000 annual itinerant operations.

(b) Established or programmed during or after 1968 (but prior to 1977) - less than 37,500 annual itinerant operations.

A control tower established or programmed during or after 1977 is a candidate for decommissioning when the sum of the ratio values as given below drops below 0.65. Tower candidates identified by this procedure will be screened in FAA headquarters using the approach described in Report No. ASP-75-4, "Establishment Criteria for Airport Traffic Control Towers."

The sum of ratio values described above is defined as:

Type Operation		Ratio Value
(1) $\frac{\text{Number of air carrier operations}}{15,000}$	=	xxxxx
(2) $\frac{\text{Number of air taxi operations}}{25,000}$	=	xxxxx
(3) $\frac{\text{Number of general aviation and military operations (local plus itinerant)}}{200,000}$	=	xxxxx
Sum of Ratio Values		xxxxx

Note: Nontowered airports with a sum of ratio value of 1.0 or greater are candidates for ATCT establishment pending the outcome of a detailed, Phase II, benefit-cost analysis.

Existing ATCT discontinuance criteria retain "grandfather clauses" which relate the discontinuance of a tower to criteria in effect at the time the tower was established or programmed. Specifically, general aviation airports have levels for discontinuance set at 18,000 or 37,500 annual itinerant operations, depending on whether the tower was established or programmed prior to or after 1968.

All airports (either air commerce or general aviation) with towers established or programmed during or after 1977 have discontinuance criteria based upon a two-phase approach. The two-phase procedure is as follows:

Phase I - Simplified Discontinuance Criteria (as published in APS-1)

When the sum of the ratio value (as computed above) drops below .65, then the control tower is a candidate for decommissioning. The .65 figure is an approximation of the level where the benefits based on activity will offset the annualized cost of O&M expenses.

Phase I criteria are primarily used for identification purposes in that towers identified under this phase are selected for further evaluation under Phase II benefit-cost analysis.

Meeting Phase I candidacy levels, therefore, will not mean automatic discontinuance. The decision will be reached on

the basis of all pertinent factors, including judgment of the operating services, the detailed benefit-cost method used by the Office of Aviation System Plans, etc.

Phase II - Benefit-Cost Analysis

The benefit-cost method will involve the determination of the following ratio value:

$$\text{Ratio Value} = \frac{\text{Dollar Value of Benefits}}{\text{Annualized O\&M Costs}}$$

If this ratio has a value of 1.0 or more, then the benefits based on activity are providing an adequate return. If the ratio drops below 1.0, then the dollar benefits are not meeting the dollar operating and maintenance costs.

Table 13 identifies 12 locations that meet existing discontinuance criteria using CY-1976 data.

Tower establishment criteria, as revised in October 1975, are based upon benefit/cost analysis. No facilities qualifying for establishment under revised criteria are forecast to qualify for discontinuance under existing criteria.

The following tabular data addresses discontinuance candidates using aircraft activity data as recorded by controllers during hours of tower operation. Specific application of existing criteria, however, will use activity data projected for a 24-hour period. This data is supplied by regional FAA personnel. Tower discontinuance candidates which appear in subsequent FAA budget proposals may, for this reason, not correspond to listings in this report. Sites listed in this section are done strictly for the sake of comparison with other criteria alternatives for approximating the number of impacted facilities.

TABLE 13

Towers Meeting Existing Criteria

Airport Type	Location	Facility Commission Date	Recorded Total Annual Itinerant CY 76 **	Discontinuance Criteria
Special (Training)	Miami, Fla. (Dade)*	7/71	2,828	37,500
AC	Kodiak, Alas.	7/72	8,381	18,000
AC	Lewisburg, W.Va.	6/74	16,537	18,000
GA	Mayaguez, P.R.	3/74	13,893	37,500
GA	Brunswick, Ga.	6/73	22,817	37,500
GA	West Memphis, Ark.	1/76	22,953	37,500
GA	Danville, Ill.	9/73	24,640	37,500
GA	Pine Bluff, Ark.	3/74	28,058	37,500
GA	Marysville, Cal.	7/73	30,958	37,500
GA	Galesburg, Ill.	6/75	32,411	37,500
GA	Appleton, Wisc.	5/71	35,571	37,500
GA	Bloomington, Ind.	9/73	37,368	37,500
	12 locations			

*NOTE: Miami (Dade-Collier) airport conducts air carrier training operations. Air traffic control personnel reference such flights by tail number, counting them as local general aviation operations. As Dade does not have commercial air carrier service, it is included as a general aviation airport.

** Recorded operations are those during hours of tower operation.

Table 14 lists towers that now qualify (CY 76) for decommissioning and the last forecasted year for meeting existing discontinuance criteria.

TABLE 14

Last Year of Discontinuance Candidacy - Existing Criteria

Tower	Last Year
Bloomington, Ind.	FY 1977
Appleton, Wisc.	FY 1977
Lewisburg, W.Va.	FY 1978
Marysville, Cal.	FY 1980
Galesburg, Ill.	FY 1980
Pine Bluff, Ark.	FY 1981
Danville, Ill.	FY 1982
Brunswick, Ga.	FY 1985
West Memphis, Ark.	FY 1990
Kodiak, Alas.	FY 1992
Mayaguez, P.R.	FY 1992
Miami (Dade), Fla.	post FY 2001

Assuming no major perturbations to the forecast in forthcoming years, the number of towers remaining candidates for discontinuance are:

End of Year	Number of ATCTs Meeting Existing Discontinuance Criteria
FY 76	12
FY 77	10
FY 78	9
FY 79	9
FY 80	7
FY 81	6
FY 82	5
FY 85	4
FY 95	1

It is evident from the above that as we wait to apply existing discontinuance criteria, we identify fewer candidates for tower decommissioning. In fact, after FY 1992, the only tower identified is Miami (Dade), which conducts air carrier training operations and, as noted above, is a special situation. The reason for this trend is twofold. The first is that aircraft operations are forecast to increase at virtually all currently towered airports. With time, all current discontinuance candidate sites will exceed criteria cutoff levels. The second reason is that towers currently must satisfy more stringent benefit-cost establishment criteria in order to qualify for establishment. These towers, due to high aircraft operation counts at the airports, are not likely to be identified under discontinuance criteria for the foreseeable future. This prevents new sites from entering the above list at some forecasted date.

The trend in identifying fewer tower candidates for discontinuance with the passage of time provides some rationale for retaining existing criteria. Recall that towers programmed during or after 1977 will be subject to benefit-cost criteria for identification for discontinuance. The grandfather clauses in current discontinuance criteria will not apply

here. As discussed above, the forecasted growth in operations will all but rule out large numbers of locations qualifying for discontinuance under grandfather clause portions of existing criteria. Finally, if we choose not to revise ATCT discontinuance criteria, we avoid exposing a number of tower sites which otherwise would be identified for decommissioning under a variety of other approaches presented in the remainder of Part C.

IX - IDENTIFY CANDIDATES FOR DISCONTINUANCE VIA BENEFIT-COST ANALYSIS

This alternative procedure to current criteria applies the methodology developed in Part A to existing tower locations regardless of programming or commissioning date. As the technique is a significant departure from existing numeric discontinuance criteria, a lead time of one year is assumed for coordination of benefit-cost criteria with FAA and industry. For this reason, forecast operations for FY 1978 obtained from the FAA Terminal Area Forecast comprise the base period.

In all, 73 tower locations (all nonradar) are identified with projected FY-1978 data. This compares to nine candidate sites when applying existing discontinuance criteria in FY 1978.

Referring to Part A, a tower is identified for discontinuance under the benefit-cost approach if costs of continued operations over 15 years exceed assigned benefits when discounted at an annual rate of 10 percent. In order for a tower to be identified in FY 1978, activity data from FY 1978 to FY 1992 (15 years) is evaluated. If the benefit minus cost (B-C) value is negative, the facility is identified as one of the 73 locations for discontinuance in FY 1978 assuming negative B-C values were taken as the criteria.

Evaluating towers identified via benefit-cost using FY 1982 as the base year requires evaluation of operations data from FY 1982 through FY 1996. Similarly, towers identified for discontinuance in FY 1986 require analyses of operations from FY 1986 through FY 2001. The expanded FAA Terminal Area Forecast was used in computerized applications of the benefit-cost approach. Locations with B-C values less than zero for base years FY 1978, FY 1982, and FY 1986 are detailed below. Towers identified for discontinuance ($B-C < 0$) in FY 1978 total 73.

If we must wait until FY 1982 to implement benefit-cost analysis, 45 towers would have negative B-C values. If B-C analysis is first applied using FY 1986 data, 24 towers are identified.

Table 15 lists these specific towers and associated benefit-cost value.

TABLE 15

Locations Having Negative Benefit-Cost Values
for FY's 1978, 1982, 1986

Tower	Benefit-Cost Value		
	FY 78	FY 82	FY 86
Paducah, Ky.	- 1		
Chico, Cal.	- 2		
College Station, Tex.	- 8		
Florence, S.C.	- 21		
Bloomington, Ill.	- 26		
Cleveland (Burke), Ohio	- 30		
Traverse City, Mich.	- 34		
Cape Girardeau, Mo.	- 47		
Goodyear, Ariz.	- 69		
Benton Harbor, Mich.	- 75		
Mayaguez, P.R.	-111	- 83	- 32
McAllen, Tex.	-119		
Imperial, Cal.	-122		
Texarkana, Ark.	-124		
Muncie, Ind.	-127		
Alexandria, La.	-138		
Terre Haute, Ind.	-141		
Enid. Okla.	-143		
Key West, Fla.	-146		
Meridian, Miss.	-156		
Lawton, Okla.	-160		
Jacksonville (Craig), Fla.	-172		
Poughkeepsie, N.Y.	-177	- 11	
Ogden, Utah	-178		
Flagstaff, Ariz.	-181		
Salinas, Cal.	-187		
Hutchinson, Kans.	-198		
Redding, Cal.	-205		
Appleton, Wisc.	-208		
New Bern, N.C.	-209	- 28	
Greenville, S.C.	-211		
Pendleton, Ore.	-243	-119	
Marion, Ill.	-247	- 40	
Merced, Cal.	-248	-31	

TABLE 15 (cont'd)

Tower	Benefit-Cost Value FY 78	FY 79	FY 80
Jackson (Hawkins), Miss.	-266	- 13	
Olympia, Wash.	-269	- 49	
St. Petersburg (Whitted), Fla.	-271	- 31	
Harlingen, Tex.	-276	- 47	
Greenville, Miss.	-288	- 85	
Kinston, N.C.	-293	-132	
Ithaca, N.Y.	-299	-111	
Brownsville, Tex.	-316	-132	
Twin Falls, Ida.	-321	-157	
Valdez, Alas.	-326	-268	-196
Bloomington, Ind.	-330	- 68	
Hickory, N.C.	-333	-130	
Fresno (Chandler), Cal.	-347	-184	- 17
Myrtle Beach, S.C.	-349	-189	
Ardmore, Okla.	-358	-128	
Santa Fe, N.M.	-384	-183	
Walla Walla, Wash.	-399	-267	-117
Tacoma (Industrial), Wash.	-405	-184	
Laredo, Tex.	-417	-217	
Hagerstown, Md.	-447	-326	-203
Valdosta, Ga.	-451	-321	-133
Athens, Ga.	-453	-271	- 22
St. Joseph, Mo.	-456	-261	- 49
Pine Bluff, Ark.	-462	-317	-157
Wheeling, W.Va.	-471	-312	-150
St. Louis (Spirit of), Mo.	-475	-339	-202
Danville, Ill.	-490	-297	- 77
Knoxville (Downtown), Tenn.	-513	-345	-145
Spartanburg, S.C.	-521	-351	-149
Owensboro, Ky.	-522	-375	-213
Marysville, Cal.	-526	-370	-193
Lewisburg, W.Va.	-550	-455	-347
Brunswick, Ga.	-552	-470	-326
Plainview, Tex.	-659	-547	-426
Hobbs, N.M.	-692	-609	-520

TABLE 15 (cont'd)

Tower	Benefit-Cost Value		
	FY 78	FY 82	FY 86
Galesburg, Ill.	-701	-598	-487
West Memphis, Ark.	-749	-663	-547
Kodiak, Alas.	-771	-686	-569
Miami (Dade), Fla.	-898	-832	-751
Total B-C Value (000)	73 Locations	45 Locations	24 Locations
	-22,070	-11,628	-6,078

In summary, this approach develops revised ATCT discontinuance criteria based upon benefit-cost analysis--in much the same manner that tower establishment criteria were revised in October 1975. The results are that 73 sites are identified with costs exceeding benefits using forecast FY-78 data. Although the impact is high, the rationale of the benefit-cost technique is to ensure that no "unsatisfactory" tower investments remain in the system.

X - IDENTIFY DISCONTINUANCE CANDIDATES VIA BENEFIT-COST ANALYSIS CONSTRAINED BY YEAR OF FUTURE TOWER REESTABLISHMENT

This alternative procedure is identical to that in the previous section in that existing towers are evaluated on the basis of benefit-cost analysis. However, due to projected increases of aircraft activity at specific locations, towered airports having negative B-C values in FY 1978 may qualify for tower establishment under the provisions of Airway Planning Standard Number One within selected years from the FY-78 base year. Satisfying ATCT establishment criteria consists of obtaining a benefit-cost ratio value of 1.0 or greater. The details of the methodology are contained in Report Number ASP-75-4. Copies of the report are available from the Office of Aviation System Plans.

Table 16 lists those locations with negative benefit-cost values in FY 78, as presented in Section IX. Table 17 identifies those sites with negative benefit-cost values in FY's 1982 and 1986. In both tables, listed are X's in one or more columns labeled Year 5, 10, or 15. An X in any column means establishment criteria are satisfied by that year. Blank entries indicate that criteria have not yet been satisfied. For B-C values generated from base year FY 1978, years 5, 10, and 15 represent FY's 82, 87, and 92, respectively. For FY 82, the column headings refer to FY's 86, 91, and 96. Finally, towers having negative B-C values in FY 86 are evaluated as qualifying for establishment in FY's 90, 95, and 2000.

Data in Table 16 can be summarized without regard to specific locations as follows:

Year B-C < 0	Number of Locations	Number of Establishment Candidates by Year			Number Not Qualifying for Establishment by Year		
		5	10	15	5	10	15
FY 1978	73	0	7	38	73	66	35
FY 1982	45	0	3	22	45	42	23
FY 1986	24	0	2	10	24	22	14

TABLE 16

Locations Having Negative Benefit-Cost Values (FY 78) with Year of Meeting Establishment Criteria Noted

Tower	Benefit-Cost	Establishment Candidate by Year 5	10	15
Paducah, Ky.	- 1***		x	x
Chico, Cal.	- 2***		x	x
College Station, Tex.	- 8***		x	x
Florence, S.C.	- 21***		x	x
Bloomington, Ill.	- 26***		x	x
Cleveland (Burke), Ohio	- 30***			x
Traverse City, Mich.	- 34***		x	x
Cape Girardeau, Mo.	- 47***		x	x
Goodyear, Ariz.	- 69***			x
Benton Harbor, Mich.	- 75***			x
Mayaguez, P.R.	-111**			
McAllen, Tex.	-119**			x
Imperial, Cal.	-122**			x
Texarkana, Ark.	-124**			x
Muncie, Ind.	-127**			x
Alexandria, La.	-138**			x
Terre Haute, Ind.	-141**			x
Enid, Okla.	-143**			x
Key West, Fla.	-146**			x
Meridian, Miss.	-156**			x
Lawton, Okla.	-160**			x
Jacksonville (Craig), Fla.	-172**			x
Poughkeepsie, N.Y.	-177**			
Ogden, Utah	-178**			x
Flagstaff, Ariz.	-181**			x
Salinas, Cal.	-187**			x
Hutchinson, Kans.	-198**			x
Redding, Cal.	-205*			x
Appleton, Wisc.	-208*			x
New Bern, N.C.	-209*			
Greenville, S.C.	-211*			x
Pendleton, Ore.	-243*			x
Marion, Ill.	-247*			x
Merced, Cal.	-248*			x

TABLE 16 (cont'd)

Tower	Benefit-Cost	Establishment Candidate by Year		
		5	10	15
Jackson (Hawkins), Miss.	-266*			x
Olympia, Wash.	-269*			
St. Petersburg (Whitted), Fla.	-271*			x
Harlingen, Tex.	-276*			x
Greenville, Miss.	-288			x
Kinston, N.C.	-293			
Ithaca, N.Y.	-299			
Brownsville, Tex.	-316			
Twin Falls, Ida.	-321			
Valdez, Alas.	-326			
Bloomington, Ind.	-330			x
Hickory, N.C.	-333			x
Fresno (Chandler), Cal.	-347			
Myrtle Beach, S.C.	-349			
Ardmore, Okla.	-358			x
Santa Fe, N.M.	-384			
Walla Walla, Wash.	-399			
Tacoma (Industrial), Wash.	-405			
Laredo, Tex.	-417			
Hagerstown, Md.	-447			
Valdosta, Ga.	-451			
Athens, Ga.	-453			
St. Joseph, Mo.	-456			
Pine Bluff, Ark.	-462			
Wheeling, W.Va.	-471			
St. Louis (Spirit of), Mo.	-475			
Danville, Ill.	-490			
Knoxville (Downtown), Tenn.	-513			
Spartanburg, S.C.	-521			
Owensboro, Ky.	-522			
Marysville, Cal.	-526			
Lewisburg, W.Va.	-550			
Brunswick, Ga.	-552			
Plainview, Tex.	-659			
Hobbs, N.M.	-692			

TABLE 16 (cont'd)

Tower	Benefit-Cost	Establishment Candidate by Year 5	10	15
Galesburg, Ill.	-701			
West Memphis, Ark.	-749			
Kodiak, Alas.	-771			
Miami (Dade), Fla.	-898			
Totals: 73 locations		0	7	38

*Asterisks pertain to references in Section XI.

TABLE 17

Locations Having Negative Benefit-Cost Values (FY 82 & FY 86) with Year of Meeting Establishment Criteria Noted

Tower	FY-82 B-C	Establishment Candidate by Year 5	10	15	FY-86 B-C	Establishment Candidate by Year 5	10	15
Poughkeepsie, N.Y.	- 11			x				
Jackson (Hawkins), Miss.	- 13		x	x				
New Bern, N.C.	- 28			x				
Merced, Cal.	- 31			x				
St. Petersburg (Whitted), Fla.	- 31		x	x				
Marion, Ill.	- 40			x				
Harlingen, Tex.	- 47			x				
Olympia, Wash.	- 49			x				
Bloomington, Ind.	- 68			x				
Mayaguez, P.R.	- 83				- 32			
Greenville, Miss.	- 85			x				
Ithaca, N.Y.	-111			x				
Pendleton, Ore.	-119		x	x				
Ardmore, Okla.	-128			x				
Hickory, N.C.	-130			x				
Kinston, N.C.	-132							
Brownsville, Tex.	-132			x				
Twin Falls, Ida.	-157							
Santa Fe, N.M.	-183			x				
Fresno (Chandler), Cal.	-184			x	- 17			x
Tacoma (Industrial), Wash.	-184			x				
Myrtle Beach, S.C.	-189							
Laredo, Tex.	-217			x				
St. Joseph, Mo.	-261			x	- 49		x	x
Valdez, Alas.	-268				-196			

TABLE 17 (cont'd)

Tower	FY-82 B-C	Establishment Candidate by Year 5	10	15	FY-82 B-C	Establishment Candidate by Year 5	10	15
Walla Walla, Wash.	-268				-117			
Athens, Ga.	-271			x	- 22		x	x
Danville, Ill.	-297			x	- 77			x
Wheeling, W.Va.	-312				-150			x
Pine Bluff, Ark.	-317				-157			x
Valdosta, Ga.	-321				-133			
Hagerstown, Md.	-326				-203			
St. Louis (Spirit of), Mo.	-339				-202			x
Knoxville (Downtown), Tenn.	-345				-145			x
Spartanburg, S.C.	-351				-149			x
Marysville, Cal.	-370				-193			
Owensboro, Ky.	-376				-213			x
Lewisburg, W.Va.	-455				-347			
Brunswick, Ga.	-470				-326			
Plainview, Tex.	-547				-426			
Galesburg, Ill.	-598				-487			
Hobbs, N.M.	-609				-520			
West Memphis, Ark.	-663				-547			
Kodiak, Alas.	-686				-569			
Miami (Dade), Fla.	-832				-751			
Totals	45	0	3	22		0	2	10

Locations having negative benefit-cost values but not qualifying for establishment at some later date can constitute an alternative approach in formulating revised discontinuance criteria based upon benefit-cost analysis. Instead of 73 locations identified through unconstrained B-C analysis, 35 sites are now selected for discontinuance in FY 1978 if we exclude all towers qualifying for establishment within 15 years. Likewise, using forecast data, 45 and 24 towers are identified for discontinuance in FY 1982 and 1986 through the unconstrained B-C technique. These numbers are reduced to 23 and 14 towers, respectively, if we exclude those that drop out due to establishment within 15 years. Other alternatives can be derived on the basis of 5- or 10-year look-ahead periods for establishment candidacy.

Like the previous approach of unconstrained benefit-cost application to ATCT discontinuance criteria, acceptance of this method ensures that existing towers are providing a worthwhile return (in dollars) on Government investments. Unlike the former approach, however, the constrained benefit-cost technique ensures that the FAA would not discontinue any towers forecast to qualify for establishment during a predefined time interval. Such a precautionary check before discontinuance could be beneficial politically as well as economically.

XI - TREATMENT OF INTANGIBLES

Benefits of an ATCT, as quantified in this analysis, include safety (reduced probability of a collision or other tower-preventable accidents) and efficiency (reduced delay for aircraft competing for takeoff and landing clearances). We would be foolhardy to assume that no additional benefits, exclusive of safety and efficiency, exist for commissioned towers.

Every legitimate analysis effort attempts to quantify those benefits which have a direct functional bearing on what is to be evaluated. In this case, towers provide enhanced safety and airport efficiency. On the other side of the coin, the complex interrelationships of facilities, especially those that are manned, with the local environment is an elusive factor, one which is not readily adaptable to benefit-cost quantification. Included here are economic benefits to the surrounding community due to facility establishment. Conversely, facility discontinuance represents a disbenefit to both the community and operating personnel and their families. In terms of tower discontinuance analysis, the economic and psychological disbenefits of tower removal can be translated to benefits of continued operation in much the same manner as credits of enhanced safety and efficiency. Unlike these, however, no analytical basis exists for quantification through historic data. An alternative to specific quantification of all conceivable benefits is to consider nonquantifiable economic and human factor benefits at commissioned towers to be a percentage of quantified benefits.

ATCT benefits of efficiency plus safety were increased by factors of 10, 20, and 30 percent to account for the existence of intangibles (if decisionmakers chose to include them in the analysis) as part of the benefit-cost determination. Table 18 compares the impact of including selected percentage factors as part of the analysis.

TABLE 18

Impact of Including Selected Percentage Factors to Account for Nonquantified Benefits

% Factor	Number of ATCT's with B-C < 0 (FY 78)	Total Discounted B-C Value (000)
0%	73	-22,070
10%	63	-17,572
20%	46	-11,936
30%	35	- 9,677

To identify specific place names, consult Table 16. This table lists all 73 sites with negative benefit-cost values. Next to each B-C value for FY 78, either zero, one, two, or three asterisks are found. Locations with three asterisks drop out (have positive B-C values) when adding a 10 percent factor; locations with two or three asterisks are eliminated when assessing locations using a 20 percent factor. Tower sites with one, two, or three asterisks drop out when using a 30 percent benefit enhancement factor. The right-hand columns of Table 16 may be used to determining when selected towers enter the system through establishment criteria in a manner described in Section X. This is summarized in the following table:

TABLE 19

Impact of Intangibles on Benefit-Cost Analysis
Constrained by Year of Future Tower Reestablishment

% Factor	Number of ATCT's with B-C < 0 (FY 78)	Number Qualifying for Establishment by Year			Number Remaining with B-C < 0 by Year		
		5	10	15	5	10	15
0%	73	0	7	38	73	66	35
10%	63	0	0	28	63	63	35
20%	46	0	0	13	46	46	33
30%	35	0	0	4	35	35	31

In conclusion, by increasing quantified benefits by fixed but arbitrary percentage levels, we may acknowledge the existence of intangibles. An important observation can be made when this approach is combined with the previous alternative of eliminating locations that qualify for establishment within selected years. (See last three columns of Table 19.) As we increase the look-ahead period from 5 to 15 years, fewer locations are obviously identified via the constrained benefit-cost technique. However, as we approach the 15-year interval, the sensitivity of the impact of adding a percentage factor drops considerably. Note for a 15-year period, the difference between a 0 percent and a 30 percent factor is only 5 sites. Thus, when considering a form of the constrained benefit-cost approach of the previous section, the treatment of intangibles may be a moot point in justifying a rationale for revised ATCT discontinuance criteria.

XII - IDENTIFICATION OF SELECTED ATCT LOCATIONS

This alternative evaluates the effect of identifying preselected numbers of tower facilities for discontinuance based upon B-C values. In other words, a decision may be to decommission the 10 "worst" locations in terms of lowest benefit-cost value.

Although there is little analytic justification for this procedure, information provided by the following table is quite useful in evaluating the impact of the benefit-cost technique in terms of discounted dollar "losses" in lieu of number of facilities.

TABLE 20

Marginal Impact of Selected ATCT Closures

X Locations with Lowest B-C Values	Percentage of Total Identified Locations	Total FY-78 B-C Value (000)	Percentage of Total B-C Value
X = 10	13.7	- 6,620	30.0
20	27.4	-11,359	51.5
30	41.1	-15,007	68.0
40	54.8	-17,854	80.9
50	68.5	-19,921	90.3
60	82.2	-21,405	97.0
70	95.9	-22,059	100.0
73	100.0	-22,070	100.0

Specific locations with X lowest values may be obtained from Table 16. As the list is arranged according to decreasing B-C value, the X lowest locations may be obtained by counting X places from the end of the table. From Table 20, observe

that the lowest 10 (or 13.7 percent) of the full 73 locations with negative B-C's comprise 30.0 percent of the total discounted B-C value of $22,070,000. Similarly, 20 (or 27.4 percent) of the lowest 73 locations comprise 51.5 percent of the total B-C value.

The rationale for choosing this method is to select an equitable point where numbers of affected tower locations are balanced against the marginal effectiveness of each site chosen for discontinuance. An awareness of the marginal impacts as listed in this section or, when considered with other approaches of Part C, may best guide the decision-maker to speak to an impact of dollar savings in lieu of number of facilities when addressing criteria for decommissioning.

XIII - OTHER CONSIDERATIONS

The previous sections of this part have attempted to provide the decisionmaker with alternative options for assessing the relative merits of continued operation of selected airport traffic control towers. Options presented here do not, by any stretch of the imagination, comprise a complete set of alternatives. Instead, Part C presents those rational choices which are most apparent for examining continued tower operations in terms of existing discontinuance or establishment criteria, or in terms of the benefit-cost procedure outlined in Part A. Each alternative can be either used alone or combined with others to form a virtually limitless selection of decision rules.

In the spirit of providing as much pertinent information as possible without clouding the fundamental economic basis for the benefit-cost approach for tower evaluation, Table 21 provides additional data from which additional decision rules can be derived.

The table presents, along with tower location and corresponding FY-78 negative B-C value, the first year by which the B-C goes zero or positive. Recall that aircraft activity data is forecast 15 years from the base year when calculating benefit-cost figures. Therefore, a B-C for FY 80 represents activity for fiscal years 1980 through 1994, inclusive. Assessing the first year of positive B-C value provides the worth of delay on tower identification through benefit-cost analysis. For instance, if B-C analysis were not applied until FY 79, the current FAA Forecast would identify 8 less sites from the current set of 73 for FY-78 application. (Specific sites identified from FY-82 and FY-86 applications of the benefit-cost procedure are presented in Section IX.)

Table 21 also presents the first year of candidacy when applying both Phase I and II current establishment criteria. Recall that application of ATCT establishment criteria is a two-phased process. The first phase consists of a simple numeric criterion as published in Airway Planning Standard Number One. This criterion is used for both identifying long-range planning requirements and selecting tower locations which are potential candidates under Phase II benefit-cost justification. In this manner, Phase I criteria screen eligible locations based on traffic activity data for subsequent economic-based benefit-cost validation under the

TABLE 21

ATCT Discontinuance
Locations Having Negative Benefit-Cost Values (FY 78)

Tower	FY-78 B-C	First Year B-C > 0	First Year Phase I Estab. Criteria Satisfied	First Year Phase II Estab. Criteria Satisfied
Paducah, Ky.	- 1	FY 79	FY 86	FY 86
Chico, Cal.	- 2	FY 79	FY 84	FY 87
College Station, Tex.	- 8	FY 79	FY 81	FY 86
Florence, S.C.	- 21	FY 79	FY 86	FY 85
Bloomington, Ill.	- 26	FY 79	FY 86	FY 86
Cleveland (Burke), Ohio	- 30	FY 79	FY 85	FY 88
Traverse City, Mich.	- 34	FY 79	FY 87	FY 86
Cape Girardeau, Mo.	- 47	FY 79	FY 87	FY 86
Goodyear, Ariz.	- 69	FY 80	FY 85	FY 88
Benton Harbor, Mich.	- 75 1/	FY 80	FY 90	FY 88
Mayaguez, P.R.	-111	FY 89	FY 91	post-2001
McAllen, Tex.	-119	FY 80	FY 89	FY 88
Imperial, Cal.	-122	FY 81	FY 87	FY 90
Texarkana, Ark.	-124	FY 81	FY 87	FY 89
Muncie, Ind.	-127	FY 80	FY 85	FY 88
Alexandria, La.	-138	FY 81	FY 92	FY 89
Terre Haute, Ind.	-141	FY 81	FY 83	FY 89
Enid, Okla.	-143	FY 81	FY 88	FY 88
Key West, Fla.	-146	FY 80	FY 83	FY 88

1/ If 10% factor were applied to B-C calculation, all towers above would have positive B-C values.

TABLE 21 (cont'd)

Tower	FY-78 B-C	First Year B-C > 0	First Year Phase I Estab. Criteria Satisfied	First Year Phase II Estab. Criteria Satisfied
Meridian, Miss.	-156	FY 81	FY 92	FY 89
Lawton, Okla.	-160	FY 81	FY 91	FY 89
Jacksonville (Craig), Fla.	-172	FY 82	FY 90	FY 91
Poughkeepsie, N.Y.	-177	FY 83	FY 87	FY 96
Ogden, Utah	-178	FY 82	FY 85	FY 90
Flagstaff, Ariz.	-181	FY 82	FY 87	FY 90
Salinas, Cal.	-187	FY 82	FY 90	FY 91
Hutchinson, Kans.	-198	FY 82	FY 86	FY 90
Redding, Cal.	-205 2/	FY 82	FY 86	FY 91
Appleton, Wisc.	-208	FY 82	FY 83	FY 91
New Bern, N.C.	-209	FY 83	FY 94	FY 94
Greenville, S.C.	-211	FY 82	FY 88	FY 89
Pendleton, Ore.	-243	FY 83	FY 90	FY 91
Marion, Ill.	-247	FY 83	FY 90	FY 92
Merced, Cal.	-248	FY 83	FY 92	FY 92
Jackson (Hawkins), Miss.	-266	FY 83	FY 88	FY 90
Olympia, Wash.	-269	FY 83	FY 89	FY 94
St. Petersburg (Whitted), Fla.	-271	FY 83	FY 87	FY 91
Harlingen, Tex.	-276 3/	FY 83	FY 89	FY 92
Greenville, Miss.	-288	FY 84	FY 95	FY 92
Kinston, N.C.	-293	FY 85	FY 2000	FY 97
Ithaca, N.Y.	-299	FY 85	FY 92	FY 93
Brownsville, Tex.	-316	FY 85	FY 97	FY 93
Twin Falls, Ida.	-321	FY 86	FY 96	FY 97
Valdez, Alas.	-326	post-2001	FY 96	post-2001

2/ If 20% factor were applied to B-C calculation, all towers above would have positive B-C values.

3/ If 30% factor were applied, all towers above would have positive B-C values.

TABLE 21 (cont'd)Fi

Tower	FY-78 B-C	First Year B-C > 0	First Year Phase I Estab. Criteria Satisfied	First Year Phase II Estab. Criteria Satisfied
Bloomington, Ind.	-330	FY 83	FY 86	FY 92
Hickory, N.C.	-333	FY 85	FY 91	FY 92
Fresno (Chandler), Cal.	-347	FY 87	FY 95	FY 96
Myrtle Beach, S.C.	-349	FY 86	FY 96	FY 98
Ardmore, Okla.	-358	FY 85	FY 89	FY 92
Santa Fe, N.M.	-384	FY 86	FY 88	FY 94
Walla Walla, Wash.	-399	FY 91	FY 93	post-2001
Tacoma (Industrial), Wash.	-405	FY 85	FY 89	FY 94
Laredo, Tex.	-417	FY 86	FY 93	FY 93
Hagerstown, Md.	-447	FY 97	FY 97	post-2001
Valdosta, Ga.	-451	FY 90	post-2001	post-2001
Athens, Ga.	-453	FY 87	FY 96	FY 95
St. Joseph, Mo.	-456	FY 87	FY 92	FY 95
Pine Bluff, Ark.	-462	FY 92	FY 94	FY 2000
Wheeling, W.Va.	-471	FY 91	FY 92	FY 99
St. Louis (Spirit of), Mo.	-475	FY 94	post-2001	FY 2000
Danville, Ill.	-490	FY 88	FY 89	FY 97
Knoxville (Downtown), Tenn.	-513	FY 90	FY 95	FY 97
Spartanburg, S.C.	-521	FY 90	FY 95	FY 97
Owensboro, Ky.	-522	FY 94	FY 93	FY 2000
Marysville, Cal.	-526	FY 93	FY 91	FY 2001
Lewisburg, W.Va.	-550	post-2001	post-2001	post-2001
Brunswick, Ga.	-552	post-2001	post-2001	post-2001
Plainview, Tex.	-659	post-2001	post-2001	post-2001
Hobbs, N.M.	-692	post-2001	post-2001	post-2001

TABLE 21 (cont'd)

Tower	FY-78 B-C	First Year B-C > 0	First Year Phase I Estab. Criteria Satisfied	First Year Phase II Estab. Criteria Satisfied
Galesburg, Ill.	-701	post-2001	post-2001	post-2001
West Memphis, Ark.	-749	post-2001	post-2001	post-2001
Kodiak, Alas.	-771	post-2001	post-2001	post-2001
Miami (Dade), Fla.	-898	post-2001	post-2001	post-2001
Totals	73 Locations			
	-22,070			

Phase II process. Calculation of the benefit-cost ratio represents the true establishment criteria, with ratios of 1.0 or more qualifying for budget submission.